



ARCHER Imagery: from search and rescue to emergency response – *experiences and challenges*

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Title slide

"A malfunction allowed the oil to spill from the Coffeyville Resources refinery on Sunday, while the plant was shutting down in advance of the flood heading toward it on the Verdigris River." [June 30, 2007]



Coffeyville flooding 7/3/2007



Coffeyville flooding - refinery 7/3/2007

"The flood engulfing homes to the rooftops carried an extra curse Tuesday as a slick of 42,000 gallons of thick crude oil floated downstream with the mud and debris, coating everything it touched with a slimy, smelly layer of goo."



Roxana Hegeman, AP, July 3, 2007

Setting the stage.....end of June was a wet one for many of the southern Great Plains states

EPA request for imagery

- **Over Coffeyville KS and Verdigris River**
 - Flooding
 - Crude oil spill
- **USGS Liaison to Northcom**
 - Request through Air Force to Civil Air Patrol
 - Post Katrina MOU
 - Facilitate emergency response





SE Kansas, southern city limits on KS-OK state line, 30 mi NE Tulsa

Flood debris and oil flowing down Verdigris River towards Lake Oologah,
drinking water for several cities including Tulsa

Civil Air Patrol

■ Background

- 1941: CAP Established Dec 1st
- 1948: Auxiliary of the United States Air Force (PL 557)
- Federally chartered nonprofit corporation
- **ALL VOLUNTEERS**

■ Advanced Technology Group

- Airborne Real-time Cueing Hyperspectral Enhanced Reconnaissance → **ARCHER**



CAP Charter

resulted in the creation of the Civil Air Patrol on Dec. 1, 1941

July 1, 1946, President Harry Truman signed Public Law 476 that incorporated CAP as a benevolent, nonprofit organization.

And on May 26, 1948, Congress passed Public Law 557 which permanently established CAP as the Auxiliary of the new U.S. Air Force.

ARCHER researched and developed under guidance of all volunteer Advanced Technology Group

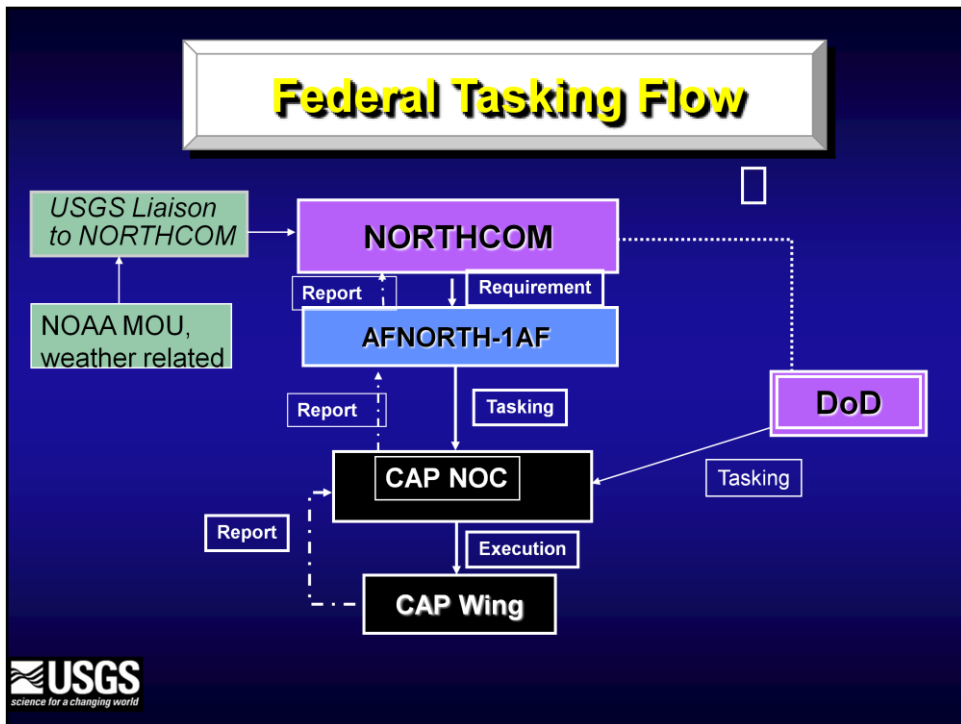
in cooperation with Naval Research Lab, Air Force Research Lab, and US Coast Guard Research & Development Ctr

16 systems plus a spare

2003 RFP, late summer 2004 awarded, 2006 last acceptance == \$6m for technology

Software by Space Computer Corporation, Hardware NovaSol Corp

Flown on Gippsland Aeronautics GA-8



More than 60% of AFNORTH missions on their Air Tasking order are CAP Missions.

NOC – National Operations Center

ARCHER System

- Integrated hardware and software
 - Advanced hyperspectral imaging (HSI) system
 - 1-m spatial resolution
 - 52 spectral bands (500 to 1100 nm, 12 nm band width)
 - Panchromatic high-resolution imaging (HRI) camera
 - 8-cm spatial resolution
 - Standard mission altitude of 2500 feet AGL and 100 knot groundspeed
 - Global positioning system (GPS) and inertial navigation system (INS)
 - Provide aircraft location, altitude, pitch, yaw, and roll



so that each image pixel can be accurately positioned (geo-registered) on a virtual map, in real time, during a mission.

1x1 m

8x8 cm or 3"x3"

Search and Rescue

- **Airborne system**
 - Georegistered image plotted on the airborne station monitor in real time
 - Identified targets highlighted with yellow or red squares
 - Pansharpened image chip of identified target displayed in separate window
 - Target location recorded in latitude, longitude, and elevation



REAL TIME

- 1) spectral signature matching (matching reflected light to spectral signatures)
- 2) anomaly detection (calculates a statistical model of all the pixels in the image to see if there is a probability that a pixel does not fit)
- 3) change detection (a pixel-by-pixel comparison of current ground conditions against ground conditions that were obtained in a previous mission over the same area)

Off-line Processing Tools

- GeoSharpen™
- GeoReg™
- GeoChange™
- Chip on Demand™



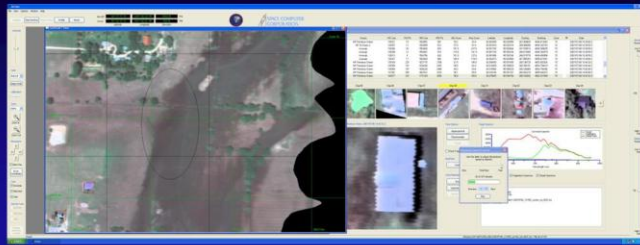
SCC has also developed off-line tools that perform specialized processing of HSI and panchromatic data. Some of these tools are designed to run in batch mode, freeing the user while the large amounts of data are processed into visual images, while other tools are more useful in a continuous data playback environment.

GeoSharpen™ – batch mode processor; converts raw HSI data into high-resolution geo-registered survey imagery.

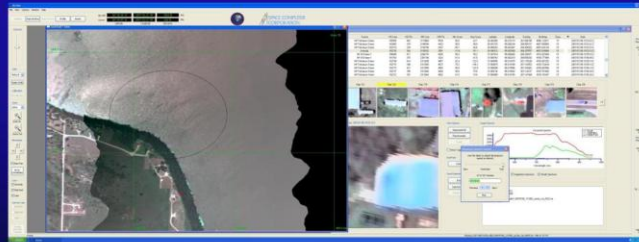
GeoReg™ – batch mode processor; geo-registers HSI or panchromatic data and displays results as viewable imagery.

GeoChange™ – data stream processor; algorithm that co-registers overlapping HSI datasets and performs pixel-level spectral difference evaluation to detect changes between the datasets.

Chip on Demand™ – algorithm that creates target for user-selected pixel.



Possible oil
contamination



Screen shots received from CAP crew

Imagery



There was no imagery available for the entire area

So we Solicited bids for commercial imagery – winning bid was Space Imaging Corp.

Preprocessing

- Envi file format
- 1 file for every minute of flying time
- GeoRegArcher - Geotif
- GeoReplay



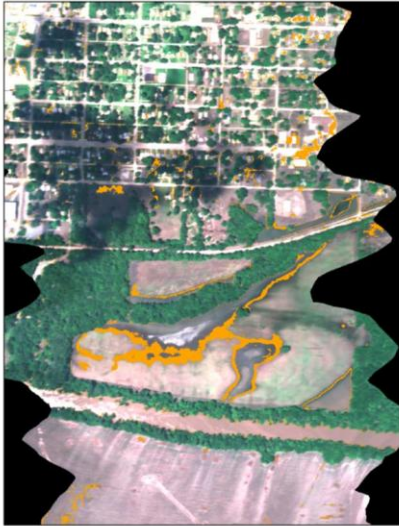
Products

- **Pan – 15 cm**
 - Files mosaicked (160)
 - Subset into manageable files
- **HSI – 1 m**
 - 4-banded (B,G,R,IR) image generated
 - Files mosaicked (160)
 - Subset into manageable files
 - Emergency management personnel able to display desired bands – natural color/color IR
- **Classification of potential spread, contamination sites**



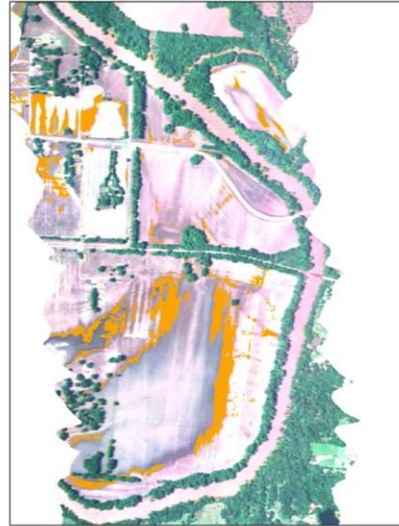
Preliminary Classification

Archer hyperspectral data flown July 7, 2007



Possible Oil Staining

Archer hyperspectral data flown July 7, 2007



Possible Oil Staining

Classification Difficulties

- Image quality
 - Signal to noise ratio – 100:1
 - Smearing/Blurring of data
 - Exceed aircraft speed
- Lack of experience and reference data
 - No ground reference data or spectra
 - False positives
 - Sensor not designed for water
- Little work on HSI use for fresh water oil spills



False positives => asphalt roads, some of the dark ponds

Water => auto-exposure (brightness) compensation goes bonkers with too much orange red compensation

Fresh water vs salt water is there a difference?

Can signatures be developed

Partial Unmixing seems good solution

Experiences

- Protocol
- Weather
- Aerial photography

- Mail
- Software
- Processing



Weather – started flying July 3 and 4, came back and flew July 6 and 7

Aerial photography – trained to fly search and rescue

Mail – next day, really 2nd day during the week

Software – what to use!!?? SCC provided trial copies of GeoReg (not for prime time) and GeoReplay – instrumental in identifying flight lines, turn arounds

Processing – 1st timers, band subset, mosaic, clip – PCI Geomatica

Lessons Learned

- Protocol / CAP – how do we do this?
 - primary goal of this activity
- Weather – no control
- Aerial photography – not same as S&R
- Mail – may not get data when expected
- Software – make sure have correct tools
- Processing – know what products needed
- Ground reference data &/or Spectral library



Imagery for on-site responders

ASAP

Procedure / Cap – established, dedicated volunteers

Weather nothing can do

Aerial photography – new to crews

Mail – know exactly what is best way to send data and tell crew

Software need to purchase at least GeoReg and GeoReplay

Processing – realize that it will take time! And may not run correctly!

Ground reference data &/or spectral library – will make hsi processing go smoother

Recommendations

- **Imagery for on-site responders - ASAP**
 - **Install GeoSharpen w/ GeoPDF capability**
- **Procedure / CAP**
 - **Need CAP to clearly define image constraints**
- **Weather**
- **Aerial photography**
 - **Provide training document on basic aerial photo collection**
- **Mail – when do you need it?**
 - **Know data origination, limitations of FedEx/UPS**



Imagery for on-site responders

Need ASAP

Install GeoSharpen w/ GeoPDF capability on ground stations

Procedure / Cap – established, dedicated volunteers
what are image distribution constraints?

Weather nothing can do

Aerial photography – new to crews, provide training manual on basics of aerial photography – things to do/avoid, add it to ARCHER crew training

Mail – know exactly what is best way to send data and tell crew, provide charge number

Software need to purchase at least GeoReg and GeoReplay

Processing – realize that it will take time! And may not run correctly!
make sure have lots of disk space!!

Ground reference data &/or spectral library – will make hsi processing go

Recommendations

- **Software**
 - Off-site location - purchase GeoReg and GeoReplay
- **Processing – what are your products?**
 - Emergency responders need pictures ASAP
- **Ground reference data**
 - If possible have someone on ground with GPS or hand held spectrometer (CAP has) to get samples of what is important (oil, contaminant)
- **Spectral library**
 - Develop spectral library for common chemicals/contaminants



Software need to purchase at least GeoReg and GeoReplay

Processing – realize that it will take time! And may not run correctly!
make sure have lots of disk space!!

Ground reference data &/or spectral library – will make hsi processing go smoother

Future Work

- HSI processing
 - Little work on fresh water oil spills
 - EPA funded MO DNR Pilot Project
 - Identify potential environmental applications and develop signature database of contaminants or environmental conditions
- Future ARCHER flights – non-emergency response
 - Employ standard HSI collection techniques
 - Mission planning, deployment
 - Collect spectra for real-time target identification
 - Ground reference/spectra collect at time of flight



Expand literature search

Is there a difference between fresh water and salt water oil spills
flooding situation – multiple contaminants

Signature database of contaminants or environmental conditions – is it possible?